s newer than these volcanic series, thus solving a question of considerable interest. From this it follows that the boulders of granite found in the basement conglomerate of the volcanic series are not derived from the granite of the district, but must have come from some other area.

Two papers were sent in by Dr. W. Mackie. The first dealt with the conditions under which manganese dioxide has been precipitated in the Elgin sandstone. The second gave the results of a series of determinations of the soluble chlorides and sulphates in the same sandstone, made with a view to test the theory that from such an examination it is possible to determine the character of the waters of the basin of deposit of sedimentary rocks. The result was of a negative character, and the author believes it is not safe to infer that the soluble salts of a deposit represent the salts of the original waters of the basin of deposition.

English geology occupied a very small part of the time of the Section. Mr. Horace B. Woodward sent an interesting note relating to the Eocenes. A section on a new railway between Axminster and Lyme Regis shows a good example of Bagshot strata near Combe Pyne Hill which serves to connect the beds of that age at Bournemouth with the deposit at Bovey Tracey in Devon. This last is now admitted to be of Bagshot age. It used to be called Miocene, but Mr. Starkie Gardner has long contended that it is equivalent to the Bournemouth Series.

A paper on the fossil flora of the Cumberland Coalfield was read by Mr. E. A. Newell Arber, who described plants from both the Whitehaven sandstone and the Coal-measures.

Mr. P. F. Kendall dealt with the Vale of Eden. He believed that he could show from the relative position of the Permian breccias or Brockrams that a movement of the Pennine faults had taken place in Permian times.

There was one paper relating to Wales. It was by Mr. W. G. Fernsides, who described some new faunas which he had obtained at Pen Morfa, near Tremadoc. He described a zone with species of high Lingula Flag type 30 feet below the Lower Tremadoc. Some 30 feet above the horizon of Ramsay's Lower Tremadoc fossils, he had found a continuous zone of Dictyonema, and had mapped its outcrop for more than five miles. Finally, some 400 feet above the Dictyonema, he had found a Shineton fauna with a number of Swedish forms and some new species.

Passing now to papers dealing with localities outside the British Isles, we may mention a paper by Dr. R. H. Traquair on fishes of the Lower Devonian roofing slate of Gemünden in Germany. They belong to the class with mailed bodies and are there associated with a fauna thoroughly marine in character, a point of considerable interest. The author showed some beautiful photographs of the fishes and of starfishes, crinoids, trilobites, corals, &c., from the slates.

Indian geology was dealt with in an interesting note by Prof. H. G. Seeley. He said that hitherto there has been no evidence of Cretaceous strata in the Salt Range of the north of India, but he was now able to bring forward an account of a series of species found by Mr. E. G. Fraser on the shoulder of Sekasar. They are of the type or age of the Upper Greensand.

Two papers dealt with Victoria, Australia. Mr. James Stirling gave some notes on a new geological map of the colony, and Dr. Smith Woodward sent an account of some observations on a new Lower Carboniferous fish-fauna from the Broken River. Attention was first drawn to these Broken River fossils some twelve years ago, and the late Sir Frederick M'Coy described them as a mixture of Devonian and Carboniferous forms. This Dr. Woodward now shows to have been a mistake; he considers them typically and essentially Carboniferous. Dr. Traquair said that he had seen the collection and could corroborate all the statements in the paper. Palæontologists might now congratulate themselves that the myth which alleged the existence of fishes of Lower and Upper Devonian and Lower Carboniferous types in the same bed had been exploded.

With regard to America, the only contribution was a paper by Dr. H. Woodward on the Middle Cambrian Trilobites of Mount Stephen, British Columbia.

Most of the Palæontological papers have already been noticed, but an interesting note on the tusks and skull of *Mastodon angustidens*, by Dr. C. W. Andrews, deserves mention.

Prof. J. Joly brought forward a suggestive paper on the viscous fusion of rock-forming minerals, which gave rise to an interesting discussion in which Mr. Teall, Prof. Grenville Cole and Dr. Johnston-Lavis took part.

Prof. J. F. Blake read a paper on the original form of sedimentary deposits. He observed that during the continuance of constant physical conditions, the seaward boundary of river-brought deposits will be a marked line. Such a line has been called an escarpment and the edge of the continental plateau, but the author believed it to be the limit of terrigenous deposits in bulk. He also considered that limestones are most likely to form deposits of lenticular shape with the long axis parallel to the shore, and when they are found to give place to shales we should infer that we are approaching a river or other source of sediment.

In conclusion, we may mention that a series of excursions to places of geological interest was arranged by Messrs. G. W. Lamplugh, J. St. J. Phillips and H. J. Seymour, and were much appreciated by the geologists present at the meeting.

CARBON AND PLANTS.[1]

IN a paper recently laid before the Royal Society, dealing with the physical processes which regulate the entry of atmospheric carbon dioxide into the leaves of plants,[2] the authors incidentally described a series of experiments relating to the rate of absorption of dilute gaseous carbon dioxide by surfaces of solutions of caustic alkali, when air containing definite small amounts of this gas is drawn over the liquid. Contrary to what might be expected from the perfect absorbing nature of the solution, and the known laws of gaseous diffusion, the amount of CO_2 absorbed by unit area of the liquid surface in unit time ceases sensibly to increase when a comparatively low velocity of the moving air current has been reached. This, however, only holds good when the proportion of CO_2 in the air stream is maintained quite constant, any slight variation in the amount at once affecting the rate of absorption. On investigation, it was found that for dilutions of carbon dioxide lying between 0·6 part and 6 parts per 10,000 of air, the rate of absorption of the carbon dioxide *is strictly proportional to its partial pressure.*

In determining the rates of gaseous diffusion of atmospheric carbon dioxide through multiperforate diaphragms extended over chambers containing perfect absorbents, the same relations between partial pressure of the gas and its absorption were found to hold good; under these conditions the amount of carbon dioxide passing through the diaphragm in a given time is also directly proportional to the density of that gas in the moving stream of air which flows over the outer surface of the diaphragm.

But this latter case exactly defines the physical conditions under which atmospheric carbon dioxide enters the tissue of a living leaf, the multiperforate diaphragm being represented by the cuticle and epidermis, pierced with numerous stomata, and the inner absorbing chamber by the intercellular spaces of the parenchyma, bounded by the chlorophyll-containing cells in which the process of photosynthesis goes on (*loc. cit.*).

The authors have now found, by enclosing the living leaves in glass cases through which air containing known proportions of CO_2 is passed, that a living leaf is really able, within certain limits, to respond to increased amounts of carbon dioxide in the air surrounding it, in such a manner as to indicate an approximate proportionality between the photosynthetic work it can accomplish and the partial pressure the gas exercises in the air bathing the leaf surface.

The following experiment may be selected from several, in illustration:—

Experiment I.—In this case, comparative experiments were made on two successive days in August, 1898, with two similar leaves, A and B of *Helianthus annuus* whilst still attached to the plant. These were exposed to the strong diffused light of a clear northern sky under as nearly as possible identical conditions, with the exception of the composition of the air drawn through the cases.

Over leaf A was drawn normal air containing 2·8 parts per 10,000 of CO_2, whilst the air passing over leaf B contained 25·53 parts CO_2 per 10,000.

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[1] Abridged from a paper on "The Influence of Varying Amounts of Carbon Dioxide in the Air on the Photosynthetic Process of Leaves and on the Mode of Growth of Plants," by Dr. Horace T. Brown, F.R.S., and Mr. F. Escombe. Read before the Royal Society on May 29.

[2] *Phil. Trans.*, B. 1900, vol. cxciii. p. 278.

Leaf A.

Area of leaf	743·1 sq. cm.
Volume of air passed per hour, reduced to normal temperature and pressure...	159·03 litres.
CO_2 content of air entering case ...	2·80 parts per 10,000.
,, ,, leaving case ...	1·64 ,, ,,
Mean CO_2 content of air in contact with leaf during experiment ..	2·22 ,, ,,
CO_2 absorbed by leaf per hour ...	18·44 c.c.
,, per sq. metre per hour	248·2 c.c.

Leaf B.

Area of leaf	863·75 sq. cm.
Volume of air passed per hour, reduced to normal temperature and pressure...	72·7 litres.
CO_2 content of air entering case ...	25·30 parts per 1000
,, ,, leaving case ...	4·12 ,, ,,
Mean CO_2 content of air in contact with leaf during experiment ...	14·82 ,, ,,
CO_2 absorbed by leaf per hour ...	155·7 c.c.
,, per sq. metre per hour	1802·8 c.c.

It is manifest that if we wish to determine the relation of the partial pressures of carbon dioxide to the rate of intake of that gas into the leaf, we must employ the values representing the mean carbon dioxide content of the air in contact with the leaf during the experiment, which may be taken as the arithmetical mean of the composition of the entering and emergent air. In the above experiment, we obtain the following relations:—

Ratio of partial pressures of CO_2 in A and B, 2·22 : 14·82 or **1 : 6·6**.

Ratio of CO_2 absorbed per sq. metre of leaf A and B in one hour, 248·2 : 1802·8 = **1 : 7·2**.

Thus by increasing the amount of CO_2 in the air passing over the leaf about sevenfold, we have, under similar conditions of illumination, increased the photosynthetic power of the leaf by a little more than the same amount.

Experiments of this nature are necessarily limited to comparatively short periods, and give no information as to how far the plant, as a whole, will respond to such changes in its atmospheric environment. When first drawing attention to these facts in 1899 (Presidential Address, British Association, Section B, Dover), it was pointed out that we were not justified, without direct experiment, in concluding that the plant would be able to avail itself indefinitely of the increased amount of plastic carbohydrate material formed in its leaves under these artificial conditions, and that translocation, metabolism and growth may have become so intimately correlated that the perfect working of the entire plant may only be possible in an atmosphere containing the normal amount of three parts of CO_2 per 10,000.

Experiments were started to test how far slightly increased amounts of CO_2 in the air would affect the dry weight of plants grown in such atmospheres, and they indicate that the plants were certainly not stimulated to increased growth by somewhat increasing the amount of CO_2 in the surrounding air. The evidence, in fact, points in the other direction, *i.e.* towards a slight diminution in the increment of dry weight, and to a less development of foliar area. There were also indications of certain morphological differences, which assumed some importance in the light of subsequent experiments. The plants grown in air slightly enriched with CO_2 had not only smaller leaves than the controls, but these leaves were of a distinctly darker green, and the internodes of the plants were decidedly shorter.

The results obtained with these preliminary experiments now induced the authors to extend their observations to a larger number of species, and arrangements were consequently made to carry out a series of experiments on a large scale. This was done in a greenhouse divided in two by a glazed partition. In one half, the plants, gourds, balsams, fuchsias, begonias, &c., were exposed to the CO_2-laden atmosphere; in the other, control plants were in ordinary air. The original paper must be consulted for experimental details and precautions.

A careful record was made of the differences in appearance of the two sets of plants on June 10, June 29 and July 13, that is to say, at 28, 47 and 61 days from the commencement of the experiment. The results are given in detail in the appendix to this paper, and may be summarised as follows:—

The effect of an increased amount of CO_2 in the air becomes in most cases apparent within a week or ten days from the commencement of the experiment, and rapidly increases as time goes on. There is a marked difference induced in the habit and general appearance of most of the plants owing to a stimulation of all axial growth, accompanied by a more or less pronounced shortening and thickening of the internodes. Usually, but not in all cases, there is an increased number of the internodes, so that the height of the two contrasted sets remains much about the same, but the chief difference of general habit is brought about by the development throughout the plant of secondary axes in the axils of the leaves, thus giving the plants grown under the influence of increased CO_2 a denser and more bushy appearance. This was particularly noticeable in the fuchsias, especially the dark-leaved variety, in which every axil bore a shoot and frequently extra axillary ones. Adventitious shoots were also developed rather freely at the base of the plants.

The leaf area of the plants under the influence of increased CO_2 was generally found to be much reduced, not so much by the formation of a smaller number of leaves as by the reduction in area of the individual leaves. This was found to be extreme in the case of the dark-leaved fuchsias, and it was also very marked in the second crop of the leaves of Impatiens. There was also produced in many of the plants a marked inward curling of the leaves, the extremes in this direction being found in the begonias and fuchsias. In the dark-leaved variety of fuchsia, the leaves were curled inwards like a watch-spring, which would doubtless tend to reduce excessive photosynthesis by preventing the normal amount of light from reaching the chloroplasts. This change of habit may, in fact, be regarded as an attempt on the part of the plant to adapt itself to its abnormal atmospheric surroundings.

The extra CO_2 in several cases induced a deeper green colour in the leaf, and in all other parts of the plant where chlorophyll was present. This was particularly noticeable in the second crop of leaves developed on the Impatiens, in the begonias and in the darker-leaved fuchsias.

On July 19, the Sachs test for starch was applied to the leaves of the two varieties of fuchsia, *Cucurbita Pepo* and *Impatiens platypetala*. In all cases, the leaves taken from the plants grown with increased CO_2 in the air showed a much larger accumulation of starch than did the leaves of the control plants. These differences were the most strongly marked in the leaves of Impatiens, which became quite black with the test.

It was, however, in the development of the *reproductive organs* of the two sets of plants that the most striking and important differences were found. Whilst the control plants in ordinary air flowered, and in some cases fruited luxuriantly, in the corresponding plants submitted to air containing 11·4 parts per 10,000 of CO_2, *inflorescence was almost totally inhibited.* With the exception of one or two sickly-looking flowers on the begonias, not a single flower-bud opened on any of the plants of this set. The plants of Impatiens, Kalanchoë and of the darker-leaved fuchsias did not even produce a flower-bud, whilst in the Nicotiana, Cucurbitas and lighter-leaved fuchsias, the small flower-buds which commenced to form were completely shed long before the time of opening.

In another series of experiments, carried out on similar lines, the air of compartment B was enriched with carbon dioxide to the extent of 6 per cent., that is to say, up to about 200 times the normal amount. The experiment extended from June 3 to August 26, and the general results both in the direction and amount of change of habit induced in the plants were so very similar to those induced in the plants with only three-and-a-half times the normal amount of CO_2 as to require no further special description. The results are, however, valuable as indicating that the observed differences cannot be due to any *direct* poisonous influence of the carbon dioxide, otherwise we should certainly expect a marked difference to be produced by increasing the amount of CO_2 from 11·4 parts per 10,000 to 600 parts per 10,000, *i.e.* more than fiftyfold, which was not the case to any appreciable extent.

The direction in which we must search for the true explanation of the effect is probably indicated by the experiments on leaves described in the early part of the paper, where it was shown that the amount of photosynthesis in the leaf lamina is, within certain ill-defined limits, a function of the partial pressure of the CO_2 in the surrounding air.

In the first series of experiments in the greenhouse, where this partial pressure was maintained at about three-and-a-half times the normal, the plants for a certain limited period must have been manufacturing carbohydrate material within their chloroplasts at least three-and-a-half times faster than those in normal air, and, although this rate of photosynthesis would perhaps not be maintained for very long, yet there would always be a general tendency for the carbohydrate supply in the leaves to be kept up to a higher point than in the controls grown in ordinary air, a fact which was shown by the leaves of set B always being gorged with starch.

Since it is quite certain that this increased photosynthesis does not to any material extent contribute to the increase of dry weight of the plants, we can only conclude that the transformation, translocation and general metabolism of the leaf-reserves under these conditions cannot keep pace with the increased tendency to produce an extra amount of plastic material from the atmosphere. Moreover, it is clear that the whole mechanism of the plant on which normal nutrition depends has its parts so completely and accurately correlated that any slight increase in the composition of the surrounding air which favours increased photosynthesis destroys the adjustment of the various parts and results in a more or less abnormal development of the plant. That any such disturbance of the economy of the plant should profoundly modify the reproductive functions might perhaps have been expected.

It is somewhat remarkable to find that all the species of flowering plants, without exception, which have been the subject of experiment appear to be accurately "tuned" to an atmospheric environment of 3 parts of CO_2 per 10,000, and that the response which they make to slight increases in this amount are in a direction altogether unfavourable to their growth and reproduction. It is not too much to say that a comparatively sudden increase of carbon dioxide in the air to an extent of about two or three times the present amount would result in the speedy destruction of nearly all our flowering plants.

To a certain extent, we may regard the facts recorded in this paper as indicating that the composition of our atmosphere as regards its carbon dioxide has remained constant, or practically constant, for a long period of time, but the authors leave altogether untouched the question of any variations of a secular kind. All we are justified in concluding is that if such atmospheric variations have occurred since the advent of flowering plants, they must have taken place so slowly as never to outrun the possible adaptation of the plants to their changing conditions.

MAGNETO-OPTICAL ROTATION IN THE INTERIOR OF ABSORPTION BANDS.

AN interesting confirmation of Voigt's theory of absorption has been afforded by an experiment by Prof. Zeeman, described in the *Proceedings* of the Amsterdam Academy of Sciences of June 25. In Voigt's theory, the separation of a spectral line by the action of a magnetic field is found as the separation of an absorption line, and the theory requires a negative rotation of the plane of polarisation in the interior of the absorption band. Now in previous experiments, such as those of Corbino, the only observed result has been a very small positive rotation. The new experiment described by Prof. Zeeman is interesting, not only as showing the existence of a negative rotation in the interior of an absorption band, but also as being in perfect quantitative agreement with Voigt's theory.

By means of a system of quartz prisms such as have been used by Fresnel in his experiment on the division of a plane polarised ray into two circularly polarised rays, a number of interference fringes were formed at right angles to the bands of a spectrum, and when light from a bright source was allowed to pass through sodium vapour and analysed with a Nicol's prism, the effect produced by the sodium absorption lines and the interference lines combined was as shown in Fig. 1. If, however, the sodium vapour was subjected to the action of a powerful magnetic field, of from fifteen to twenty thousand units, the effects shown in Fig. 2 were observed. It will be noticed that the fringes moved upwards along the components of the doublets, whereas the parts of the fringes *between* the components became disconnected from the exterior parts and *moved downwards*. As the density of the sodium was increased, the interior portions slid downwards with increasing velocity, and at a certain stage those in the interior, more particularly of the D_1 line, resembled inverted arrows. At last with increasing proportions of sodium these arrows entirely disappeared, and it was observed that this disappearance was more rapid with the D_2 lines than with the D_1 lines. Among subsidiary features it was noticed that the slope of the interior interference fringes is greater towards the side of the greater wave-lengths than towards the violet. The interior fringes also show a slight asymmetry, so that, *e.g.*, the points of the arrows in Fig. 2 ought to be asymmetrical.

Using very much denser vapours, however, results were obtained agreeing more with the experiments of Macaluso and Corbino. Figs. 3 and 4 show the effects with field intensities of about 4500 and 10,700 units respectively, and the absorption bands appear to contain horizontal parts of an interference fringe which have undergone a very small displacement *upwards* by the action of the field. These horizontal parts are, however, broader and more ill defined than the markings in the circumstances previously described. It is possible that the conditions assumed in these later experiments are different from those required by the theory, and that some explanation of the difference in the two kinds of phenomena may be found.

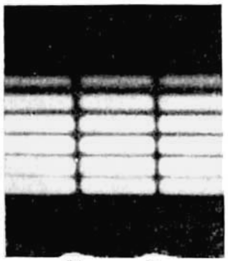

FIG. 1.

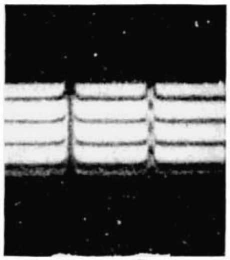

FIG. 2.

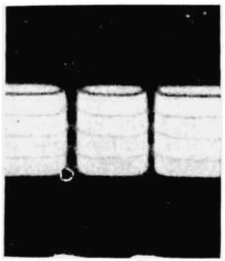

FIG. 3.

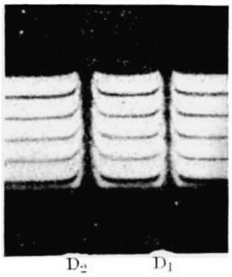

FIG. 4.

In a paper communicated to the Reale Accademia dei Lincei of Rome, also on May 31, Prof. W. Voigt discusses the same phenomenon on a theoretical basis, and quotes the formula

$$n\chi = \mathrm{KP}\frac{(\Delta^2 - \mathrm{P}^2 - 1)}{(\Delta^2 + \mathrm{P}^2 + 1)^2 - 4\Delta^2\mathrm{P}^2}.$$

where χ denotes the angular rotation of the plane of polarisation, n the geometrical mean of the indices of refraction of the two waves propagated in the vapour, P is proportional to the magnetic field, and Δ is proportional to the number of wave-lengths in the distance of the point considered from the primitive position of the absorption band. From this formula are obtained the curves shown in Fig. 5, which correspond to the values $P=0{\cdot}5$, $P=1{\cdot}5$, $P=3{\cdot}0$, and the resemblance between these curves and Prof. Zeeman's photographs will be readily noticed.

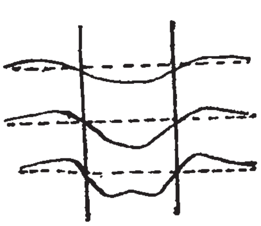

FIG. 5.